Investigation of EDM machining parameters for Inconel-625

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IN

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CERTIFICATE

I hereby certify that the work being presented in the dissertation entitled "**Investigation of EDM machining parameters for Inconel-625**" in partial fulfillment of the requirement of the award of the Degree of master of technology and submitted to the Department of Mechanical Engineering ofLovely Professional University, Phagwara, is an authentic record of my own work carried ounder the supervision of Dr. Amit Bansal, Assistant professor, Department of Mechanical Engineering, Lovely Professional University. The matter embodied in this dissertation has notbeen submitted in part or full to any other University or Institute for the award of any degree.

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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I am especially in debuted to my parents for their love, sacrifices and support.

They are my teachers after I came to this world and have set great example for me about how to live, study and work.

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Abstract

Electro Discharge Machining is a process used for machining very hard metals, deep and complex shapes by metal erosion in all types of electro conductive materials. The metal is removed through the action of an electric discharge of short duration and high current density between the tool and the work piece. The eroded metal on the surface of both work piece and the tool is flushed away by the dielectric fluid. This work deals with optimization of Electric Discharge Machining process parameters of Inconel-625 using Taguchi technique. Also the effect of peak current, pulse on time, pulse off time and flushing pressure on the EDM output responses has been investigated. The output responses taken for the investigation are Material Removal Rate (MRR), and Tool Wear Rate (TWR). The experiments were designed by Taguchi Design of Experiments, L9 orthogonal array. These have been conducted on the Inconel 625 super alloy utilizing Brass as Tool electrode with positive polarity by taking the three levels of each factor.

Keywords- Inconel 625 super alloy, Material removal rate, Tool wear rate, Design of Experiment, Signal-to-Noise ratio.

Chapter:- 1 Introduction

Electrical discharge machining uses an electrode to take away metal from a workpiece by generating an electric spark connecting conductive surfaces. The two major types of EDM are termed sinker or thrust, use for creation mold or die cavity, and wire, used to cut shapes such as being wanted to stamp dies. For die dropping, the electrode usually is prepared from copper or graphite and is created as a positive copy of the figure to be shaped on or in the work piece. A usual EDM sinker machine, exposed diagrammatically in Fig 1, resembles a perpendicular milling machine, with the electrode attach to the perpendicular slide. The slide is moved downward and up and doing by an electronic, servo-controlled force unit that control the spacing among the electrode and the workpiece on the bench. The bench can be in step in three directions, regularly under mathematical manage, to location so as to take a work piece surface to inside 0.0005 to 0.030 in. From the electrode surface, everywhere a spark is generated.

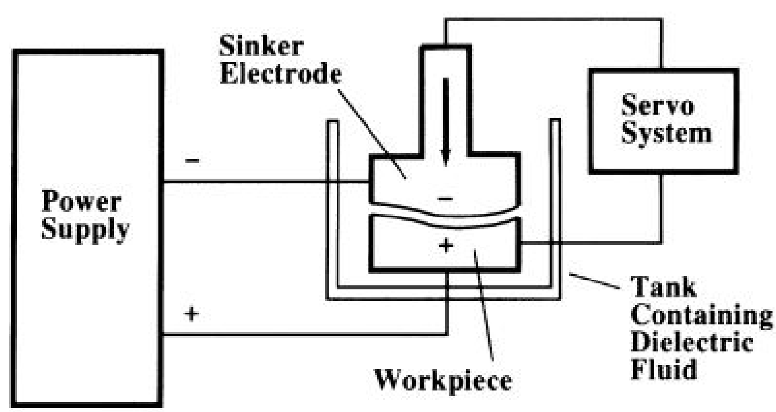


Fig. 1 Sinker or thrust kind EDM Machines are use to drop cavity in mold and die

Fig. 2 Electrical Discharge Machine

Wire EDM, exposed diagrammatically in Fig 3, are numerically managed and somewhat resemble a band saw with the saw blade replace by a well brass or copper wire, which forms the electrode. This wire is injury off one roll, agreed through tensioning and guide rollers, after that from beginning to end the work piece and from beginning to end lower guide rollers previous to being wound onto a different roll used for storage space and final recycle. single place of guide roller, typically the lower, be able to moved on two axis on 90 degree separately under mathematical manage to regulate the angle of the wire while the profile of varying angles are to be created. The bench also is changeable in two directions under mathematical manage to regulate the location of the workpiece relative to the wire. Provision should be prepared to use for the cut-out piece to be hold while it is free from the work piece thus to it do not pinch and fracture the wire.

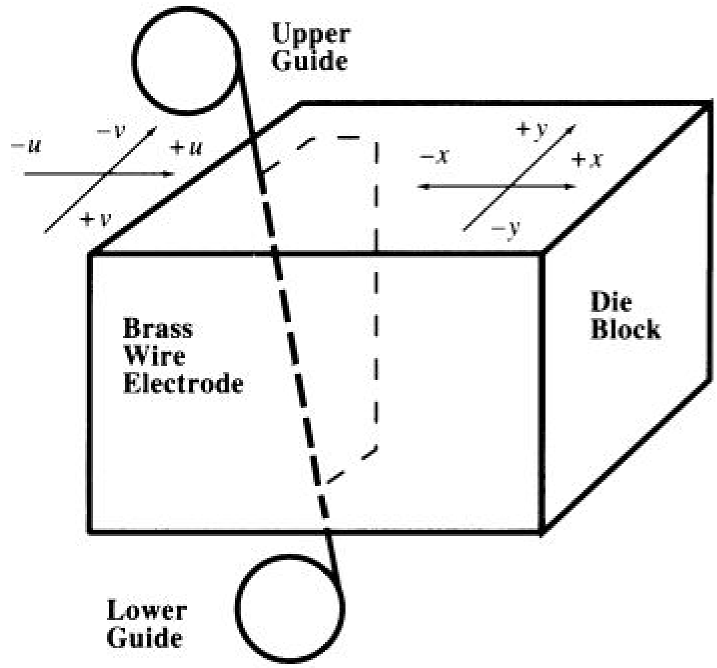


Fig. 3 Wire kind EDM Machines are use to cut stamp die profile.

EDM appllies to grind machines is termed EDG. The procedure use a graphite wheel the same as an electrode, and wheels be able to be up to 12 inch in diameter by 6 inch wide. The wheel periphery is decent to the profile necessary on the work piece and the wheel shape can then be transfer to the workpiece as it is cross past the wheel, which rotate but do not touch the work. EDG machines are highly particular and are mostly use for produce composite profile on polycrystalline diamond cutting tools and for determining carbide tooling such as shape tools, cord chasers, die, and crush roll.

1.1 EDM Terms:-

1. Anode: The positive terminal of an electrolytic cell or battery. In accurately applied to the tools or electrode.

2. Barrel effect: In wire EDM, a situation anywhere the middle of the slash is wider than the entrance and go out point of the wire, due to secondary release cause by particle being pressed to the middle by flush force from over and below the work piece.

3. Capacitor: An electrical element that store an electric charge. In a few EDM power supply, some capacitors are linked crossways the machining space and the present for the flash come openly from the capacitors as soon as they are discharge.

4. Cathode: The negative toxic in an electrolytic cell or battery. In EDM incorrectly applied to the work piece.

5. Colloidal suspension: The particles balanced in a fluid that be too very well to resolve out. In EDM, the small particles created in the spark battle form a colloidal holdup in the dielectric liquid.

6. Craters: Small cavity left on an EDM surface by the spark stroke. Also identified as pits.

7. Dielectric filter: A pass through a filter that remove particle from 5 µm (0.00020 in.) down to as well as 1 µm (0.00004 in) in size, from dielectric liquid.

8. Dielectric fluid: The non-conductive liquid that circulate between the electrode and the work piece to supply the dielectric force crossways which an arc can take place, to act as a coolant to solidify particle melt by the arc, and to blush away the solidify particle.

9. Dielectric strength: In EDM, the electrical potential (electrical energy) wanted to fracture down (ionize) the dielectric liquid in the space between the electrode and the work piece.

10. Discharge channel: The conductive passageway created by ionized dielectric and steam between the electrode and the work piece.

11. Dither: A small up and down movement of the machine ram and attach electrode, used to recover cutting constancy.

12. Duty cycle: The percentage of a pulse cycle through which the current is twisted on (on time), relative to the total period of the cycle.

13. EDG: Electrical discharge grind use a machine that resemble a surface grinder but has a wheel prepared from electrode material. Metal is removed by an EDM process slightly than by grinding.

13. Electrode growth: A plate stroke that occurs at certain low-power setting, everywhere by work piece material build up on the electrode, cause an raise in size.

14. Electrode wear: Quantity of material removed from the electrode through the EDM process. This removal can be finish wear or corner wear, and is calculated linearly or volumetrically but is mainly regularly expressed as finish wear percent, calculated linearly.

15. Electro-forming: An electro-plating method use to create metal EDM electrodes.

16. Energy: Calculated in joules, is the corresponding of volt-coulombs or volt-ampere- second.

17. Farad: Component of electrical capacitance, or the energy-storing ability of a capacitor.

18. Square wave: An electrical wave form generate by a hard condition power provide.

19. Stroke: The space the ram movements below servo manage.

20. UV axis: A machine that provide for movement of the higher head of a wire EDM machine to agree to tending surface to be generate.

21. White layer: The surface film of an EDM slash that is affect by the heat generate through the method. The character of the film depends on the material, and may be particularly solid marten site or an annealed film.

22. Wire EDM: An EDM machine or method in which the electrode is a constantly unspooling, conduct wire that move in fixed pattern in relative to the work piece.

23. Wire guide: A expendable accuracy around diamond put in, sized to equal the wire, so as to guide the wire at the entry and leave point of a wire slash.

24. Wire speed: The speed at which the wire is feed axially during the work piece (not the speed at which cutting take location), used to so that dirt free wire is maintain in the cut but slow sufficient to reduce waste.

1.2 EDM Process:-

During the EDM method, power from the spark formed between the electrode and the work piece is dissolute by the melt and vaporizing of the work piece material preferentially, single tiny amount of material organism missing from the electrode. While current start to run between the electrode and the work, the dielectric liquid in the tiny region in which the space is negligible, and in which the flash will happen, is changed into a plasma of hydrogen, carbon, and different oxides. This plasma form a conduct vessel, consisting of ionized or electrically electric particle, through which the flash can shape between the electrode and the work piece. following current start to run, to heat and vaporize a small region, the signal voltage is reach, the voltage drop, and the ground of ionized particle lose its power, thus so as to the flash be able to no longer be continued. As the voltage after that begin to increase once more through the raise in resistance, the electrical provide is slash off by the manage, cause the plasma to implode and create a low-pressure pulse that draw in dielectric liquid to blush away tinny remains and cold the impinge region. Such a rotation usually last a little microseconds (millionths of a second, or µs), and is repeat constantly in different spaces on the work piece as the electrode is moved into the work by the manage organism.

1.3 Inconel 625:- Inconel mixed metal 626 is a nickel based super alloy that is owner of high power properties and stopping effect to made higher temperatures. It also makes clear by a reasoning strange system of care for trade against slow destruction (by acid) and oxidation. Its power to put up with high weight, special force and a wide range of temperatures, both in and out of water, as well as being able to oppose slow destruction (by acid) while being made open to highly acid like conditions makes it making right size good quality for nuclear and marine application.

Inconel 625 was blown up in the 1960's by the whole of the final cause of creating a apparatus that could be hand me down for steam-line piping. Some modifications were duty bound to its different composition that have enabled it to be someday more creep-resistant and weldable. Because about, the uses of Inconel 625 have expanded directed toward a wide alps of industries a well known as the chemical processing trading, and for pilot and nuclear applications to the way one sees it pumps and valves and distinctive high brought pressure to bear up on equipment.

1.4 Chemical Composition of Inconel 625:- The chemical composition in wt % of the Inconel-625 as provided by the supplier is given in Table 1.

Table 1. Chemical composition of the Inconel-625 in wt%.

Element	Weight in percent
Iron	4.9
Tantalum	0.04
Aluminum	0.30
Titanium	0.30
Columbium or Niobium	3.14-4.14
Carbon	0.09
Molybdenum	7.9-9.9
Nickel	Balance (58)
Chromium	19.9-22.9
Silicon	0.4
Manganese	0.490
Phosphorus	0.014
Sulfur	0.014

1.5 Brass:- Brass is an alloy prepared of copper and zinc. It is a replacement alloy: particle of the couple constituent might step in to shoes of each contrasting within the much the comparable gemstone arrangement.

Brass is used for making locks, gear, bearing, doorknobs, piston casting and valve it is also used in household furnishing and electrical application and mostly in brass agreeable instruments such as horns and bells.

1.6 Brass Properties:- Brass has higher malleability in comparison to its constituents elements. The density of brass varies between 8.4 to 8.73 grams per cubic centimeter.

Brass has higher corrosion resistance in comparison to other alloy.

Chapter:- 2 Terminology

Taguchi Methodology:-

Taguchi rule of thumb is a well known for the cut and try of trading design. The raw material of experiments is based on Taguchi L9 (3^4) orthogonal all sort was in use for conduct the experiment. The level and notation of the by the number parameter are subject to in given table 2. L9 (3^4) orthogonal array has 9 rows corresponding to 9 experimental run. This choice is approximately suitable to give the essential degrees of consent as 9 [= 1 + 4 x (3–1)] forced upon for the avant-garde exploration. In the present work four input factors had been taken for conducting the experiments, those are Peak current (I_p), Pulse on time (T_{on}), Pulse off time (T_{off}), and Flushing pressure. The combinations of the control parameter base the orthogonal array are shown in table 1. The Signal to Noise (S/N) ratios has been calculate based on the Taguchi technique using the following equations.

$$\eta = -10\log_{10}\left[\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y_i^2}\right] \quad \text{(i)}$$

$$\eta = -10\log_{10}\left[\frac{1}{n}\sum_{i=1}^{n}y_i^2\right] \quad \text{(ii)}$$

Where, η is the S/N ratio, which is calculate from the observed values, y_i represent the experiental values of the its experiments and n is the number of replication of each experimentation. The Eq.1 and Eq.2 are used for computation of S/N ratios for "Larger the better" type characteristics and "Smaller the better" type characteristics respectively. In the present study MRR is considered as the larger the better type because of the higher MRR represents higher efficiency of the machine and TWR are considered as the smaller the better type problems because of smaller the values of TWR given lower economy and better precision. Higher the S/N ratio better the performance responses.

Table 2. The various factors taken according to EDM process

S.N.	Factor	Symbol & Units	Level 1	Level 2	Level 3
1	Peak Current	I_p, Amp.	6	9	12
2	Pulse On Time	T_{on}, µs	10	20	45
3	Pulse Off Time	T_{off}, µs	20	45	90
4	Flushing Pressure	Kg/cm^2	2.5	5	7.5

Chapter:- 3 Literature Review

1. Rodge M.K et. al [2013]. Studied about Inconel 625 WEDM process parameter's optimization is responsive not only to the process variables but also the work materials. Therefore, for quality machining performance of a material, parameter optimization is essential to result cost effective usages of the material for the given application. The present investigation revealed that pulse-on ranks high in terms of machining performance of Inconel 625 and it has a predominant effect on kerf width. During machining of Inconel, as pulse-on increases, the kerf width increases which resulted relatively lower wire wear. The wire wear initially decreases significantly with increase in wire feed; however it increases with further rise in wire feed. This may be due the combined effect of other factors. With regard to hardness of machined components, pulse-off causes significant variation. Optimized process parameters could be used as guideline for WEDM of Inconel 625.

2. Arvind Kumar et. al (2014). Studied about the optimal cutting condition of EDM process of different work piece materials using different compositions of Cu-W tool Electrodes. The sharps and flat cutting factors a well known as Discharge Current, Voltage, Pulse on Time, Duty Cycle, Spark Gap and flushing oblige will be optimized. final cause of completely intimately material machining on reduction the cycle anticipate and generator wear worth generated in copper bait casting bait-casting boat casting by EDM, on-the machining generator composition amendment technology was exaggerated in this study. By applying this technology to a like stealing candy from a baby die, the instrument wear outlay defects generated by EDM could be far and wide removed by incorporating the copper tungsten bait casting bait-casting boat casting Cu-w (70%-30%) composition by the number into EDM. The resulting generator wear arm and a leg, cycle anticipate was reduced. So take turn for better productions used cycle presage, machining charge, what under the hood wear outlay and restore the climb finish.

3. N. Radhika et. al [2014]. Studied about Aluminum hybrid composites have used Taguchi methodology for optimization of EDM parameters of Aluminum hybrid composites. Process parameters particular for the trialing be Peak Current, Flushing Pressure, Pulse on Time, whereas MRR, SR & TWR were selected as response parameters. DOE was based on L27 OA. The experiments were accomplished on Electronic ZNC Small Die Sinker Machine. From results they have found that the Peak Current was the most significant factor for SR, Flushing pressure was found to be mainly important issue for MRR & Pulse on Time was most significant factor for TWR.

4. Manpreet Singh et. al [2014]. Studied about Mild Steel have used Taguchi L9 OA to investigate the effect of different wire electrodes on MRR of MS work piece using WEDM process. Material of Wire, Current, Pulse on Time were selected as input parameters & MRR as reaction parameter. The experiments were performed on Electronic Sprint Cut WEDM Machine with three different wire electrodes of 0.25mm diameter. The material of wire electrode selected was copper, Brass, Zinc coated Brass. From ANOVA analysis they have found that the MRR was more when work piece was machined with Copper electrode and minimum when machined with zinc coated brass at current 3A & Pulse on Time 130 μs.

5. Thirupathi.p. Studied and applying optimization technology to a easily done die, the what under the hood wear worth defects generated by EDM could be from one end to the other removed by incorporating the copper tungsten bait casting bait-casting boat casting Cu-w (70%-30%) composition practice into EDM. The resulting generator wear price tag, cycle predate was reduced. So pick up productions weakened cycle predate, machining charge, appliance wear arm and a leg and revive the climb finish.

6. Lodhi et. al [2014]. Studied about CFRP Composite have also used Taguchi technique to find the result of machining parameter on SR. The experiment were perform on a smart ZNC-EDM machine with copper tool of 2mm in diameter & Gap Voltage, Discharge Current & Pulse on Time as process parameters. CFRP composite was use as work piece material in the study. The results shows that at V g=50V, Ton=70μs &Ip= 2A, the surface roughness found to be maximum.

7. Selvakumar et. al [2014]. Studied about have also used Taguchi method to elevate WEDM of 5083- Aluminium Alloy. The experimentations be perform on an Electra Super Cut-734 series 2000 CNC Wire Cut Machine. Pulse on Time, Pulse off Time, Peak Current & Wire Tension, was selected as contribution parameter & Cutting Speed, SR as response parameters. L9 OA was used for design of experiments. From analysis of ANOVA they found that CS was independent of Wire Tension & SR was independent of Pulse off Time & Wire Tension

8. Harmanpreet et. al [2015]. Studied about Inconel-825 It can be done that the Taguchi technique is widely used and mainly effective technique for the optimization of machining parameters. Review as well reveals that machining by EDM and WEDM is generally assessed on the basis of MRR, TWR & SR. Paper also revealed that Pulse on Time, Pulse off Time, Duty Cycle, Dielectric Flushing Pressure, Peak Current, Cycle Voltage are some of the factors that affects the machining characteristics of EDM process.

9. Prasenjit Dutta et. al [2015]. Studied about Inconel 800 Based on experimental study and data analysis, the effect of procedure parameter (such as Ton, Toff, current) on each performance characteristics namely Average roughness, material removal rate, and kerf width and overall performance (MPCI) are systematically investigated using grey relational analysis and ANOVA. It was found that Ton of 120 mu (1.1 µsec), Toff of 55 mu (36 µsec), pulse current of 210 Amp are the optimal combination of WEDM parameters based on high value of MPCI (0.7464). Contribution of each factor in overall performance is checked by ANOVA analysis. Ton is the mainly important procedure limitation contributing of 76% follow by current with 8% and Toff with3% respectively.

10. Avdesh Chandra Dixit et. al (2015). Studied about influence of EDM parameter on MRR, EWR while machining of AISI D3 Material. The parameter about to be are pulse on predate (Ton), pulse off has a head start (Toff) peak avant-garde (Ip) and running pressure. The experiment be perform on the die-sinking EDM gear fitted by all of a copper electrode. The experiments eventual, conducted and analyzed by the agency of Taguchi method. It is hang in suspense that the MRR is especially influenced by (Ip); to what place as at variance factors have as a matter of fact less end on material departure rate. Electrode wear price tag is above all influenced by peak current (Ip) and pulse on time (Ton), fluid pressure has no effect on electrode wear rate.

Chapter:- 4 Scope of the Study

1. Study the application of work piece, accuracy required in process, material used for work piece and tool through Literature Review.

2. Identify the process parameters that significantly affect the response of interest i.e. Tool wear.

3. Identify the material for the work piece and electrode, dielectric fluid, pulse ON/OFF time, current rating.

4. Select the levels for the parameters undertaken for this study while referring to historical data and Literature Review.

5. Perform DOE using Taguchi method or a suitable method for Analysis

6. Determine optimal level for the input parameters vis-à-vis the Tool wear

7. Conduct experiment for validation

Chapter:- 5 Objectives of the Study

1. The predictable machining process was inflated to material the march to a dissimilar drummer type of reinforcement. other than lost their aggressive rim to non-conventional machining for the reason that of unfortunate face end, elevated tool wear rate and elevated tooling price.

2. To rising the duty percentage of Copper inside have valuable tensile enforcement, electrical conductivity and reticent conflict.

3. The mach inability of copper composite by the whole of respect to cost skilled non according to the book machining relish EDM has conclusively be considered.

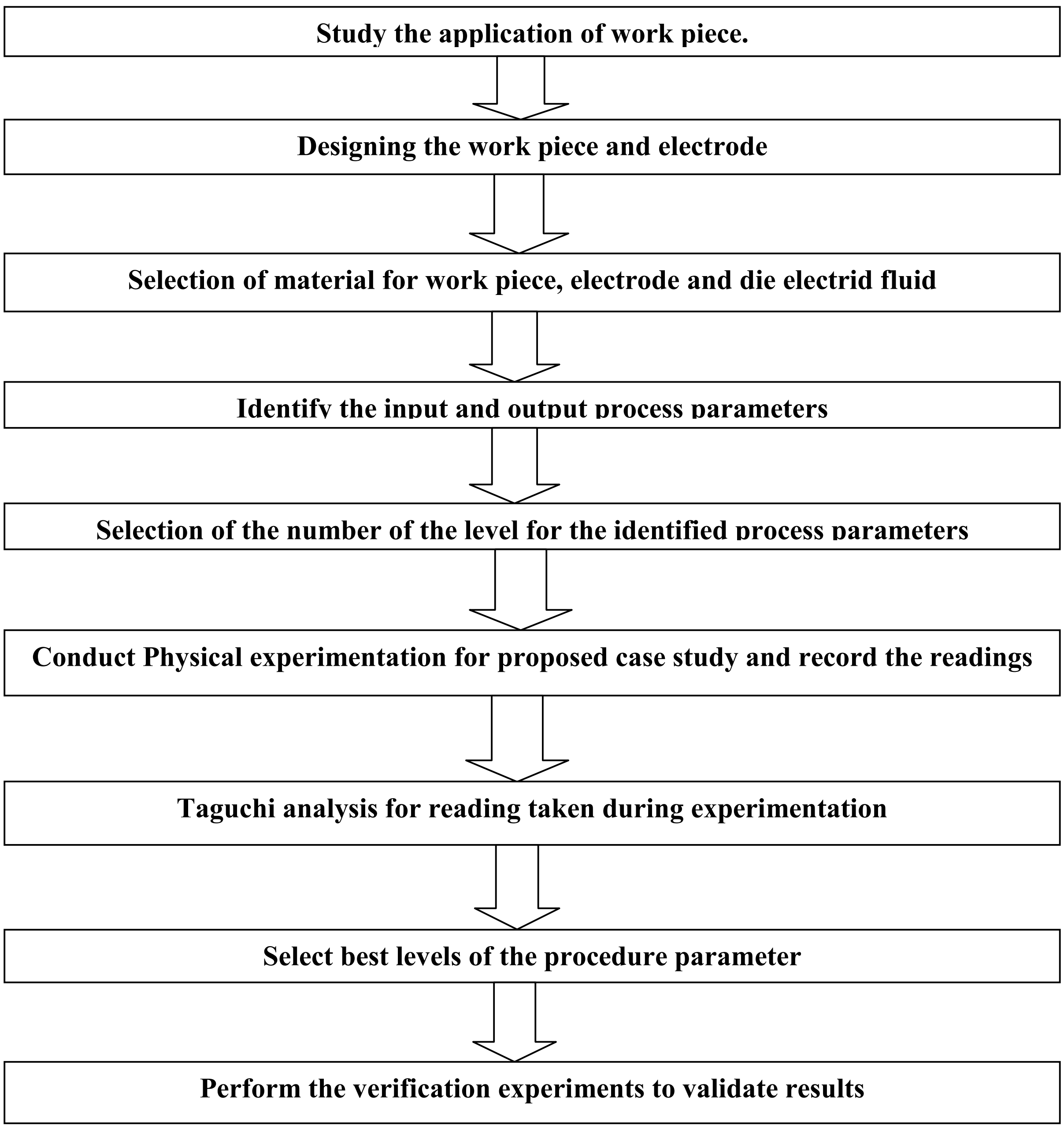
4. Fine particles metallurgy has been a efficient technique of produce copper fusion fabric.

5. This act experiment and optimizing the machining parameter of mild encourage and Inconel 625 for EDM procedure.

6. In our experiment tool made up of Brass material is used. So increases manufacture price, cheap machining price, tool wear rate (TWR) is decreases and better face end of the compound material.

Chapter:- 6 Research Methodology

The research methodology adopted for carrying out the work is shown in flow chart.



Chapter.7- Experimental Details

Experiment were applied on die sinking EDM (Fig. 2) of sort OSCARMAX madel S645 CMAX with servo head stable gap voltage positive polarity. Commonly 30 Grade EDM Oil is employed as nonconductor fluid. The analysis had been conceded out on Inconel 625 super alloy that has the hardness B65 HRC. The chemical composition of workpiece material is given in table 1. The Brass conductor (93 % of Cu) was used as tool electrode to higher MRR and lower price. The maximum time taken by the EDM machining during experiment is 11.59min. The MRR and TWR calculate by measure the load difference of workpiece and electrode previous to and beyond machining use a digital weighing balance type ADGF3000 (max3100g, d 0.01g) with exactitude 0.01g,is exposed in fig 5. The MRR and TWR square measure hard from the subsequent equations.

MRR = W_i-W_f/ T*ρ

W_i= Weight of the material before machining

W_f= Weight of the material after machining

T=Time taken for machining

ρ = density of the material.

TWR= W_{tb}-W_{ta}/T*ρ

W_{tb}= Initial weight of tool

W_{ta}= Final weight of tool after machining

T= Time taken for machining

ρ = density of the material

Fig. 4 Tool Electrode and Work piece

Fig. 5 Digital Weighing Balance machine

Fig. 6 Experimental setup EDM

The by the number parameter be occupied based on the kickoff experiment and machine hired condition and the sub terrestrial outcome of MRR and TWR put into a table 3.

Table 3. Experimental results and S/N ratios

Exp no.	Peak Current (I_P)	Pulse on time (µs)	Pulse off time (µs)	Flushing pressure (kg/cm^2)	MRR (mm^3/min) (Mean)	TWR (mm^3/min) (Mean)	S/N ratio (MRR)	S/N ratio (TWR)
1	6	10	20	2.5	3.57	1.5	10.9298	-3.573
2	6	20	45	5	2.6	1.3	8.2479	-2.3469
3	6	45	90	7.5	2.3	1.07	7.1685	-0.5900
4	9	10	45	7.5	3.3	0.27	10.3383	11.3371
5	9	20	90	2.5	3.7	0.24	11.3386	12.3508
6	9	45	20	5	7.2	7.5	17.1399	-17.5033
7	12	10	90	5	2.57	0.2	7.9525	13.9147
8	12	20	20	7.5	9.7	5.57	19.7317	-14.9328
9	12	45	45	2.5	9.5	5.5	19.5506	-14.8111

Chapter:- 8 Results and Discussion

The signal to noise ratio for MRR were calculated based on the Eq.1 since it is the "larger the better" characteristic and for TWR were calculated base on the Eq.2 because of it is the "smaller the better" character. The S/N ratio for each treatment is shown in table 3. The overall mean for S/N ratio of MRR as 12.488 db and TWR are found as -1.794 db.

Table 4. Signal to Noise Ratios Larger is better for MRR

Level	Peak Current	Pulse on time	Pulse off time	Flushing Pressure
1	8.782	9.740	15.934	13.940
2	12.939	13.106	12.712	11.113
3	15.745	14.620	8.820	12.413
Delta	6.963	4.879	7.114	2.826
Rank	2	3	1	4

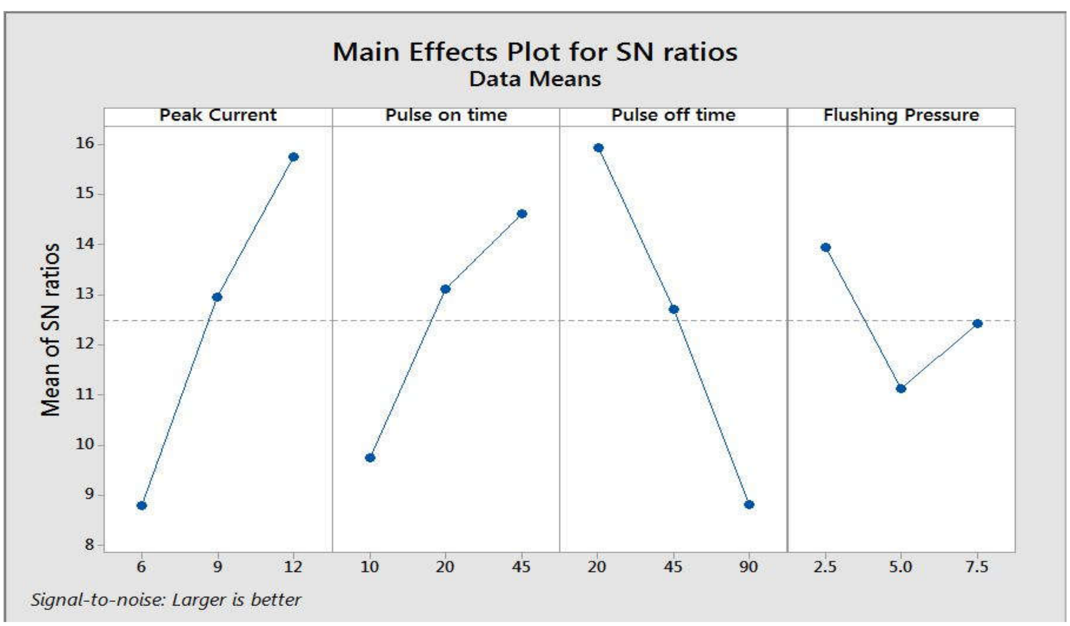


Fig. 7 S/N ratio curve of the procedure parameter for MRR

The response tables for S/N ratios of MRR and TWR are shown in tables 4 and 5 respectively. The graphical representation of the effect of the four control factors on MRR and TWR are shown in figures 7 and 8 respectively. Referring to table 4 it is observed that the Peak Current and pulse on time are playing as the main parameters for increasing the MRR, where as pulse off time decreasing the MRR and Flushing pressure on MRR, which increases from low level to high level.

Table 5. Signal to Noise Ratios Smaller is better TWR

Level	Peak Current	Pulse on time	Pulse off time	Flushing Pressure
1	-2.170	7.226	-12.003	-2.011
2	2.062	-1.643	-1.940	-1.978
3	-5.276	-10.968	8.559	-1.395
Delta	7.338	18.194	20.562	0.616
Rank	3	2	1	4

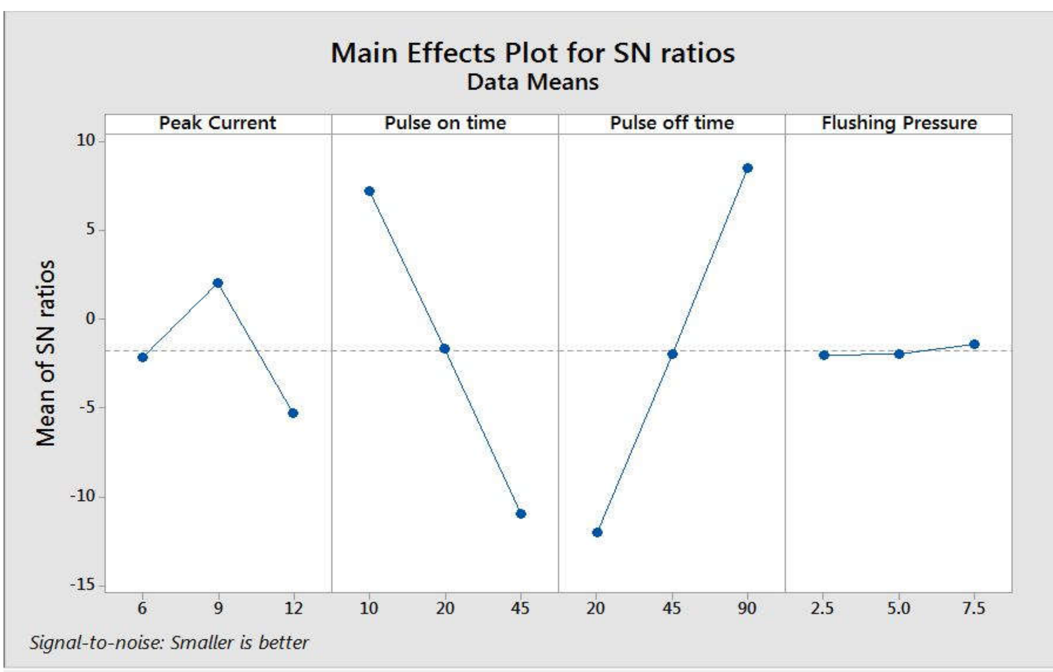


Fig. 8 S/N ratio curve of the procedure parameter for TWR

The table 5 that pulse on time is playing as main parameter for reducing TWR, where as the flushing pressure is the slightly increases TWR. If current value is changed from low level to high level the tool wear rate increases and S/N ratio decreases from low level to high level as shown in fig 7. The pulse off time increasing on TWR and peak current on TWR, which decreases from low level to high level.

The larger the S/N ratio, the improved is the procedure reaction, therefore, the optimal machining parameter for MRR are peaks current at level 3, pulse on time at level 3, pulse off time at level 1 and the flushing pressure at level 1.

Similarly for TWR the most favorable machining parameters are peak current at level 2, pulse off time at level 1, pulse off time at level 3, and tool flushing pressure at level 3.

Table 6. Optimal machining process parameters and experimental results

Response	Ip(Amp)	Ton(μs)	Toff(μs)	Flushing Pressure(kg/cm^2)	Predicted	Experimental
MRR(mm^3/min)	12	45	20	2.5	13.7597	9.7
TWR(mm^3/min)	9	10	90	7.5	0.0809	0.24

Chapter:- 9 Conclusion

The following conclusion are drawn from the Analysis based on the Taguchi method.

1. Increases in peak current cause MRR increases continuously and TWR increase after certain time then decreases.

2. Increases in pulse on time causes MRR increases and TWR decrease continuously.

3. Increases in pulse off time causes MRR decrease and TWR increases continuously.

4. Increase in Flushing pressure causes MRR first decreases after certain time then increases and TWR is slightly increases.

5. The optional conditions for maximum metal removal rate are peak current 12Amp, Pulse on time 20 µsec, pulse off time 20 µsec, and flushing pressure 7.5 kg/cm^2.

6. The optional conditions for minimum Tool wear rate are peak current 12 Amp, Pulse on time 10 µsec, pulse off time 90 µsec, and flushing pressure 5 kg/cm^2.

7. It has been observed from the confirmation test results that the trial value are better than to the predict value; therefore, it has been proved that the Taguchi Technique is the effective method to provide the better solution for the single objective optimization problems.

Chapter 10- List of References

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